Cost Estimating for Level of Effort (LOE) Activities

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Outline

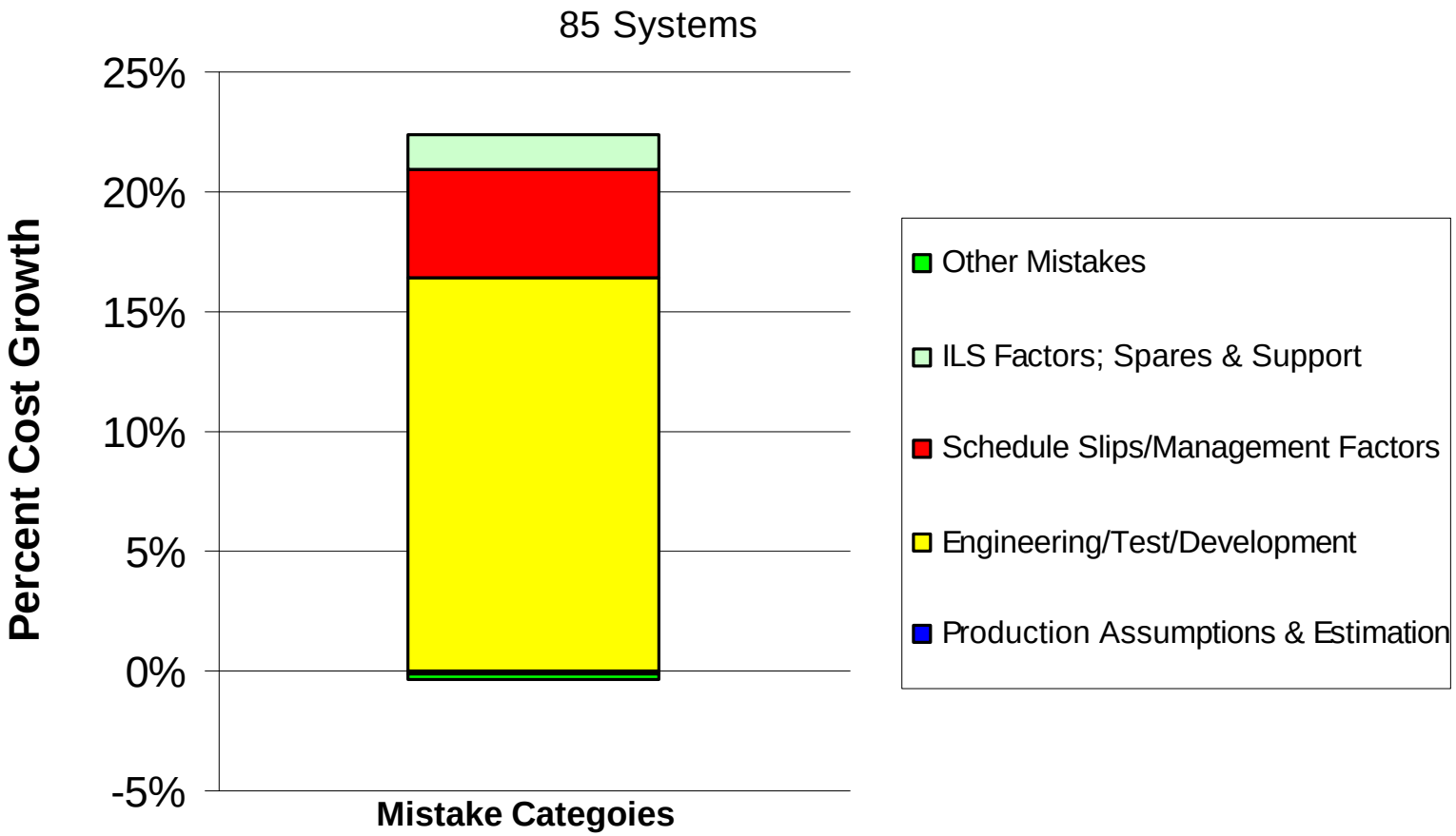
- R&D cost growth
- Sources of errors
- A little math
- Interesting examples
- A better approach for LOE activities

Cost Growth from Milestone II

(Baseline is estimated cost at Milestone II)

	RDTE	Procurement	Total
Total Cost Growth			
Arithmetic Average	44%	28%	28%
Mistakes Cost Growth			
Arithmetic Average	22%	13%	14%
Number of Systems	85	86	87

RDT&E Cost Growth Attributable to Mistakes



What's the source of estimating errors?

- General approach
  - time element
  - inter-WBS correlation
  - ground rules
- Inadequate risk analysis
  - precision versus accuracy
- Use of factors
  - enhance biases
  - increase imprecision

See the talks Thursday and Friday mornings.

Factors and Biases

In estimating RDT&E, generally assume the following model:

PME	procurement-based costs	$f_P * T_1$
	task-based efforts	C_{TB}
	factors on the above	$f_1 * (f_P * T_1 + C_{TB})$
System-level LOE		$f_2 * PME$

Estimated system cost = $(1 + f_2)*(1 + f_1)*(f_P * T_1 + C_{TB})$

Actual system cost = $(1 + \beta_2 f_2)*(1 + \beta_1 f_1)*(\beta_P f_P * \beta_T T_1 + \beta_C C_{TB})$

Compounding the Error

$\beta_T = 1.1$

$\beta_C = \beta_P = \beta_1 = \beta_2 = 1.05$

$f_1 = 0.2$

$f_2 = 0.5$

$C_{TB}/(f_P T_1) = 0.333$

} 16% growth in RDT&E

If $\beta_C = 1.2$, then 20% growth.

Growing the Variance

If X and Y are independent with means μ_X, μ_Y

$$\frac{\mathrm{var}(XY)}{\mu_X^2\,\mu_Y^2} = \frac{\mathrm{var}(X)\,\mathrm{var}(Y)}{\mu_X^2\,\mu_Y^2} + \frac{\mathrm{var}(X)}{\mu_X^2} + \frac{\mathrm{var}(Y)}{\mu_Y^2}$$

$$\approx \frac{\mathrm{var}(X)}{\mu_X^2} + \frac{\mathrm{var}(Y)}{\mu_Y^2}$$

Growing the Variance (cont'd)

More generally,

$$\frac{\mathrm{var}(X_1 X_2 \cdots X_n)}{\mu_{X_1}^2 \, \mu_{X_2}^2 \cdots \mu_{X_n}^2} \approx \sum_i \frac{\mathrm{var}(X_i)}{\mu_{X_i}^2}$$

Worst case,

$$\frac{\sigma(X_1 X_2 \cdots X_n)}{\mu_{X_1} \, \mu_{X_2} \cdots \mu_{X_n}} \approx \sqrt{n} \, \frac{\sigma(X_1)}{\mu_{X_1}}$$

A Few Examples

- Total solar irradiance sensor on NPOESS

$$\text{NRE estimate} = \frac{41.3}{33.1} \times \frac{.209}{.491} \times \$15\text{M}$$

adj. for weight

adj. for extent of design mod.

analogous system NRE cost

- Shuttle heat shield assembly

$$.840(1551)^{.5} \times .40 \times .685 \times 1.032$$

CER

degree of new design

wtd. avg. of other complexities

inflation

Examples (cont'd)

- MADCAM: T1 estimating tool for Milstar communications payload electronic boxes

  Box T1 cost = (costs of assembled boards, power supply, and enclosure) x (1 + box IA&T cost factor) x (1 + manuf. support cost factor) x (platform conversion factor)

  assembled boards cost = total board area x $\prod_i$ % area in i^{th} tech. x $\frac{\$}{\text{area}}$ for i^{th} tech.

What’s a good alternative to factors?

LOE Estimating Example Using Equivalent Staffing Profiles

- RTIP Overview
- LOE Estimation Comparison
  - PME Percentage
  - Equivalent Staffing Profile
- Equivalent Staffing Candidates
- Data sources
- Data Normalization

LOE Estimating Example (cont'd)

- Dealing with Schedule Variance
- Sample Program Data
- Updating the Estimate
- Using an LOE Estimate as a Management Tool

Radar Technology Insertion Program (RTIP)

- ~ $1B EMD Program
- Active Electronically Scanned Array (AESA)
- Significant Performance Increases in Synthetic Aperture Radar (SAR) and Moving Target Indicator (MTI)
- NATO Airborne Ground Surveillance (AGS)
- 108 Month Development Profile
- Previous Historical Data Available

LOE Estimation

- Estimated Based on Equivalent Staffing
- Time Phasing of Data
- Schedule Dependency
- Problems with PME Relationship
  - Subcontract Value Interdependence
  - Accounting for Process Improvement Initiatives
  - Tying Estimate to Scope of Tasks

LOE Estimation (cont'd)

- Difficulties with Equivalent Staffing Method
  - Time/Effort Consuming
  - Data Dependent
  - Contractor or DCMC Interface
- Still Dependent on Scope and Complexity
- Must be Careful not to "Double Count" Effort

LOE Personnel

- "Personnel whose effort is directly affected by schedule variance"
  - Program Management
  - Project Control
  - Subcontract Management
  - System Engineering
  - Integrated Logistic Support
  - Quality Control

Data Sources

- Contractor Cost Data Report

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- CPR

  Program Office

- Contractor Data

  Contractor Accounting Systems

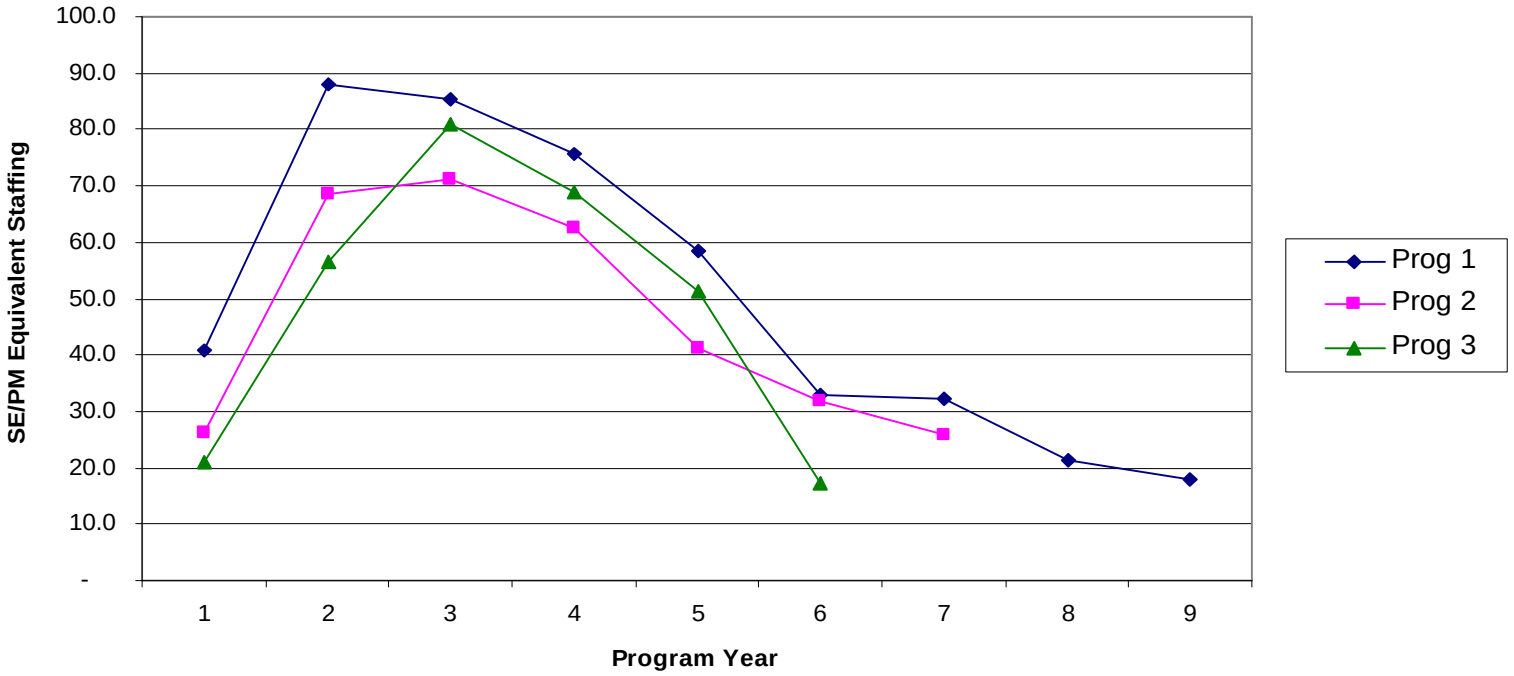
Data Normalization Issues

- Accounting Changes
- Definitions
- Period of Performance
- Program Scope/Complexity
- Data Requirements
- Other

Schedule Variance

- Budgetary Changes
- Program Slips
- Effect on SE/PM v. PME
  - Forecasted
  - Actual
- Linking LOE to PME Cost Growth
  - PME Variables
  - Hardware Requirements

Sample Program Data



	Duration	PME	SE/PM	% of PME	Ave Staff
Program 1	108	1,080.0	353	32.7%	50.3
Program 2	84	1,175.0	255	21.7%	46.8
Program 3	72	990.0	231	23.3%	49.3
	(Months)	($M)	($M)		(EP)

Evolution of Your Estimate

- Updating Estimates
- Impact of Schedule Slips
  - Non-Symmetrical Impact on PME Estimating Methodologies
  - Easily Assessed
- Quantity Changes
- Use as a Management Tool

Backup slides

Decisions and Mistakes Cost Growth Categories

- Decisions
  - Requirements, configuration, and variant changes
  - Schedule changes, and acquisition strategy changes (e.g., multiyear procurement, dual-sourcing), and management initiatives
  - ILS changes, and spares and support changes
  - External program factors (FMS, strikes, etc.)
  - Other discretionary changes
- Mistakes
  - Production assumption and estimation changes
  - Engineering, test, and development changes
  - ILS changes, and spares and support changes not attributable to post-milestone II discretionary decisions
  - Schedule slips attributable to technical problems
  - Other changes not attributable to discretionary changes

Distribution of Mistakes RDT&E Cost Growth